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Hexcel Research
Reference: 6065

November 17, 1964

Picatinny Arsenal
Dover, New Jersey

Attention: Procurement and Production Directorate
SMUPA - PBI

Subject: Contract No. DA-04-200-AMC-477 (A)
Development and Evaluation of a Lightweight
Aluminum Honeycomb Case
Monthly Progress Report No. 9

Gentlemen:

Enclosed is the report describing the work done on the subject

contract during the months of September and October, 1964. The report

was prepared by the Advanced Structures Group, Research Division,

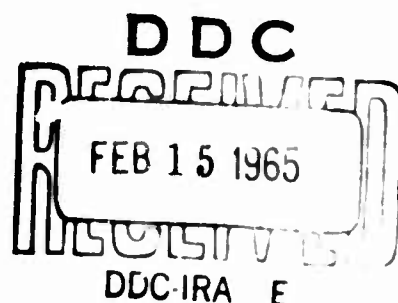Hexcel Products Inc., Berkeley 10, California.

Included as attachments are (1) Statement of Man Hours Expended -

September and October, 1964, (2) Schedule showing Current Progress -

September and October, 1964, and (3) Schedule showing Program of

Ensuing Activities - November and December, 1964.

Yours very truly,

E. C. Vicars
Research Director

ECV:skw

Attachments (3)

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REPORT OF PROGRESS

SEPTEMBER AND OCTOBER, 1964

Cases 9 and 10 were fabricated and tested during the months of September and October, 1964. A summary of design changes and test results is given below.

Design Modifications

1. Case HXL-9-477: The amount of the energy absorption core was increased from 17" to 27-1/2" along the length of the case. In addition, 16 longitudinal slots were cut out of the core as shown in Figures 1 and 3.

   As part of the work that constituted Case 9, several rings of honeycomb were manufactured and tested for the purpose of determining the dimensions of slots that would give the best impact response for the entire case. These are shown in Figure 3.

2. Case HXL-10-477: The size of the slots in the energy absorption core was increased slightly over that of Case 9, as shown in Figure 2.

In all other respects, Cases 9 and 10 were identical with Case HXL-8-477.

Movies

Motion pictures were taken to provide a visual record of the
environmental tests performed on Cases 8 and 10. The record includes
pictures of the equipment used and the conduct of the following tests:

1. Case HXL-8-477

    a) temperature shock

    b) transportation vibration

2. Case HXL-10-477

    a) hydrostatic pressure

    b) impact

High speed (200 frames/second) pictures were taken of the impact
tests to better illustrate the crashing action of the honeycomb core.

Test Results

1. Hydrostatic Pressure Test:

    The pressure test was not performed on Case 9. Case 10 was
twice subjected to an external pressure for a duration of five (5)
minutes. At the completion of pressure cycles, the case was filled
with approximately one (1) foot of water. By visual inspection,
it was determined that the leaks were caused by poor sealing at
the electrical connector and the locking device on the front cap.
Design changes are being made on Case 11 to correct these
deficiencies.

2. Impact Tests - General Comments:

The results of tests on Cases 6, 6a, 7 and 8 indicated the need for design changes to reduce the payload response to impact from side drops. In addition, the problem of payload vibration within the case structure has made it necessary to clarify the methods being used for data acquisition and analysis.

When the payload is decelerated during impact, the total acceleration consists of the sum of the response to the forcing function and the transient free vibration. Since the payload-case system is continuous (as opposed to a lumped parameter system), the free vibration component is composed of an infinite sequence of mode shapes and frequencies. This means that the total acceleration experienced by the payload will be different at every point even though the response to the forcing function is approximately the same everywhere.

To cope with this situation, the project engineers at Picatinny Arsenal and Hexcel have agreed that the following criteria will be used in evaluating the case design:

1. The acceleration of the payload will be measured at the mounting ring and at the free end of the payload (see Figure 4).

2. The case design will be considered satisfactory with regard to impact response if the faired value of the acceleration-time

relationship, measured at the mounting ring, is less than the contract specification (27 g's laterally, 40 g's axially).

For side drops, the average peak value of the faired a-t curve (measured at the mounting ring) on Cases 6 through 8 was 33.3 g's. In an effort to reduce this value to 27 g's, impact tests were performed on several rings of honeycomb core as shown in Figure 3. Tests on ring segments are simpler to perform and yield more accurate measurements than tests on the entire case. The results of tests on the rings led to the conclusion that the acceleration response of the payload could be decreased by increasing the amount of core along the length of the cylinder providing there was a means to reduce the crushing strength of the honeycomb at large deflections. Drop tests on Cases 9 and 10 demonstrated that this conclusion was correct.

The reasoning behind this is as follows. The best energy absorber (for this application) would be one that absorbs energy at a constant rate. This requires a honeycomb configuration that crushes with a constant force, a condition that is difficult to achieve with the increasing area that results from crushing a cylindrically shaped object.

Without modification, i.e. no slots, honeycomb of this configuration yields a force-deflection curve where the force increases almost linearly with deflection until the total kinetic energy is absorbed. To approach the ideal more closely, an additional 10 lineal inches of honeycomb were added to the case. The additional honeycomb increased

the total crushing force at small deflections, while the slots

weaken the core, resulting in a more nearly constant force at larger

deflections.   These relations are shown below in Figures a, b and c.
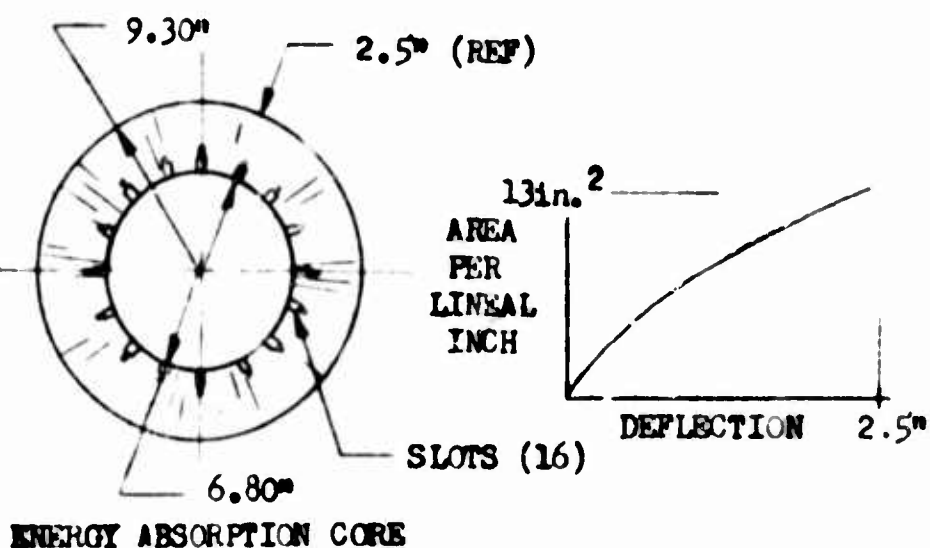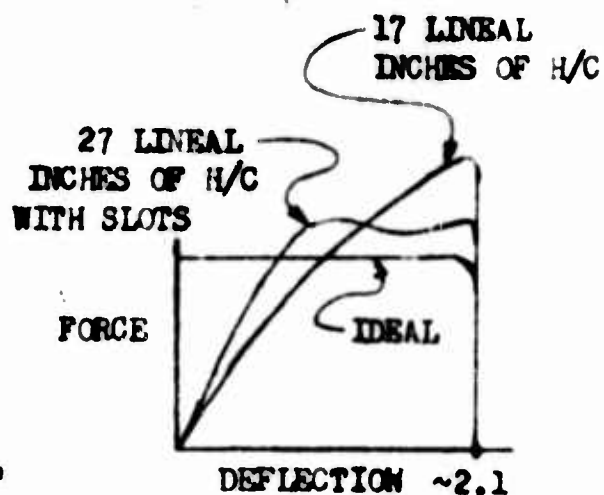

ENERGY ABSORPTION CORE

FIGURE a.   FIGURE b.   FIGURE c.

Case HXL-9-477:

Typical results for Case 9 are shown in Figures 5, 6, 7, 8 and 9. For all drop tests, the accelerometers were mounted as shown on Figure 4. The acceleration response of the honeycomb ring shown in Figure 5 came closer to yielding a constant force-deflection relationship than any of the other rings tested. The unit loading of this ring was the equivalent of 27-1/2 inches of honeycomb on the full-length case.

Figure 6 shows the acceleration response for Case 9, drop 3 (9-3). Case 9 was tested without skin and end caps so that the payload response could be more easily correlated with the impact tests on the honeycomb rings.

Figure 7 shows the acceleration, velocity and displacement responses for both the fixed and free ends of the payload during drop 9-3. These were obtained by double integration of the faired acceleration-time curve. The force-deflection relationship at each end of the payload is obtained by eliminating the parameter time from the a-t relationship and the displacement-time relationship. The force-deflection relationships for 9-3 are shown on Figure 8.

Figure 9 is a comparison of various force-deflection relationships. The curve labeled "Parson's Ring" was supposed to give the same response as the "Best Ring" (from Figure 5). The difference in response was attributed to manufacturing variations in the shape of the slots.

Also shown are drops 1 and 3 for Case 9. Complete results of the drop tests on Case 9 are shown in Table 1. The average peak value of faired a-t curve, measured at the mounting ring, was 26.0 g's for 4 drops.

There were no end drops or edge drops performed on Case 9.

Case HXL-10-477:

The accelerometers were mounted as shown on Figure 4.

Side Drops: The average peak value (for 3 drops) of the faired a-t curve was 28.4 g's at the mounting ring and 29.4 g's at the free end of the payload.

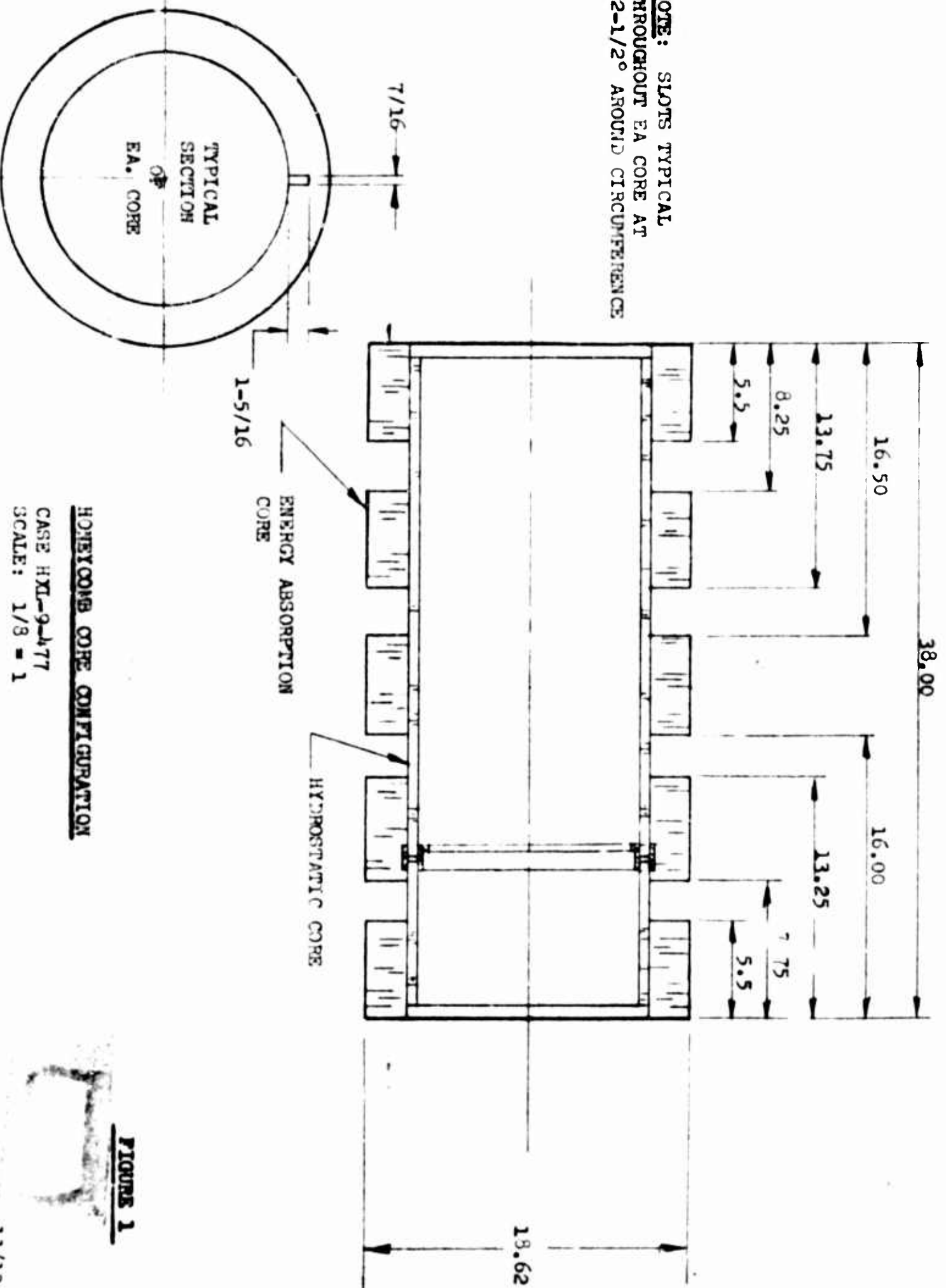End Drops: The peak value of the faired a-t curve was 24.2 g's, average for 2 drops.

Edge Drops: One edge drop was performed, yielding a maximum value of 16.5 g's on faired a-t curve.

The results of all drops are shown on Table 2.

Attachments:

1. Statement of man hours expended during September and October, 1964.

2. Program of activities during September and October, 1964.

3. Projected schedule of activities for November and December, 1964.

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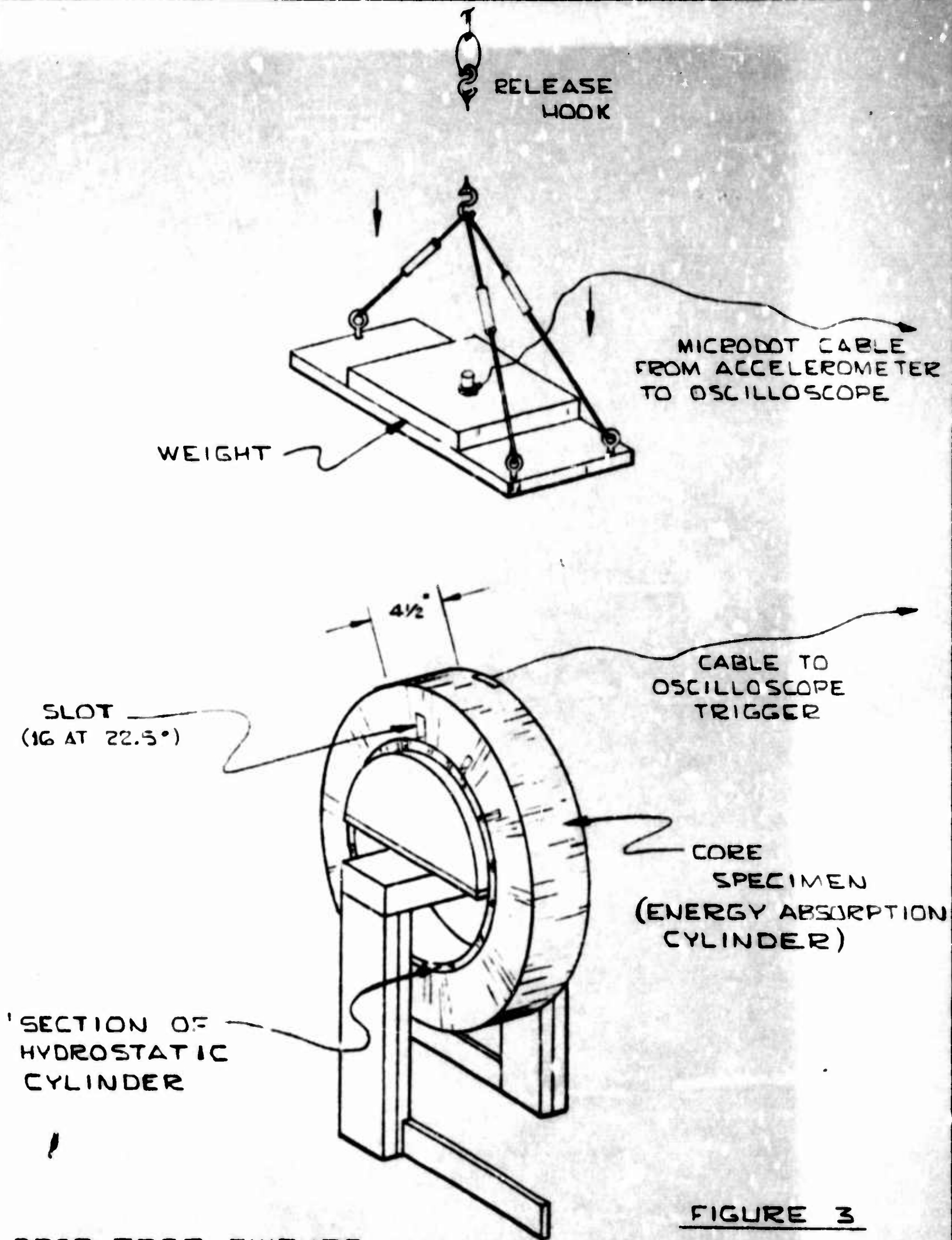NOTE: SLOTS TYPICAL THROUGHOUT EA CORE AT 22-1/2° AROUND CIRCUMFERENCE

TYPICAL SECTION OF EA. CORE

7/16

1-5/16

ENERGY ABSORPTION CORE

HYDROSTATIC CORE

16.50
13.75
8.25
5.5

38.00

16.00
13.25
7.75
5.5

18.62

HONEYCOMB CORE CONFIGURATION
CASE HXL-9-477
SCALE: 1/8 = 1

FIGURE 1

11/13/64 F.P.

RELEASE
HOOK

MICRODOT CABLE
FROM ACCELEROMETER
TO OSCILLOSCOPE

WEIGHT

4½"

SLOT
(16 AT 22.5°)

CABLE TO
OSCILLOSCOPE
TRIGGER

CORE
SPECIMEN
(ENERGY ABSORPTION
CYLINDER)

SECTION OF
HYDROSTATIC
CYLINDER

FIGURE 3

DROP TEST FIXTURE
NOT TO SCALE

PROJECT 6065   10/13/64

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FIGURE 2

11/13/64 F.P.

NOTE: SLOTS TYPICAL THROUGHOUT E. A. CORE AT 22-1/2° AROUND CIRCUMFERENCE

SLOT

TYPICAL SIZE OF E.A. CORE

13/16

7/16

11/16

5/8

HONEYCOMB PART CONFIGURATION
CORE: TYPE Q-57
SCARF: 1/8 ± ?"

ENERGY ABSORPTION CORE

HYDRODYNAMIC CORE

REAR GAP

5.5

8.25

13.75

16.50

38.00

16.00

13.25

7.75

5.0

5.0 TYP.

14.62

18.62

8 BOLTS
1.5 DIA AT 45°
BOTTOM CAPS

LOCATION OF ACCELEROMETERS (3)
FOR DROP TESTS ON CASES 9 & 10

FIGURE 4

ACCELEROMETER

CASE

FREE END

PAYLOAD

22.5°

ACCELEROMETERS

FIXED END

ADAPTER RING

NOT TO SCALE

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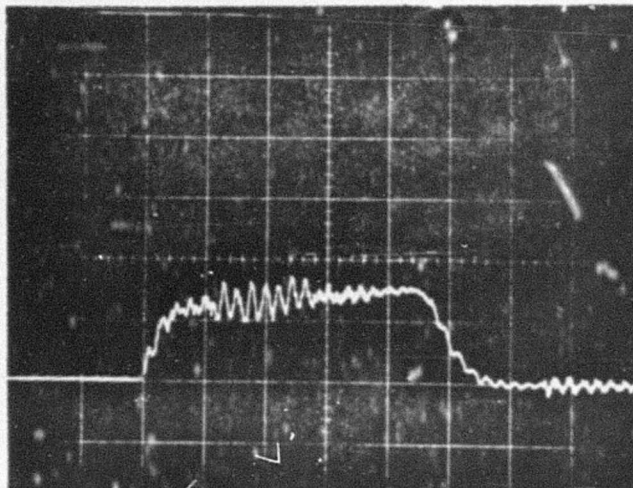REP: 6065   8/11/64   F.P.

FIGURE 5 , ACCELERATION RESPONSE OF HONEYCOMB RING

Vertical Calibration: 14.6 g's/cm
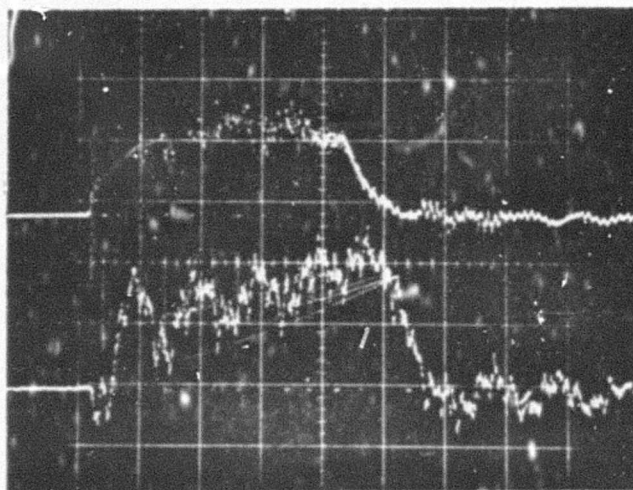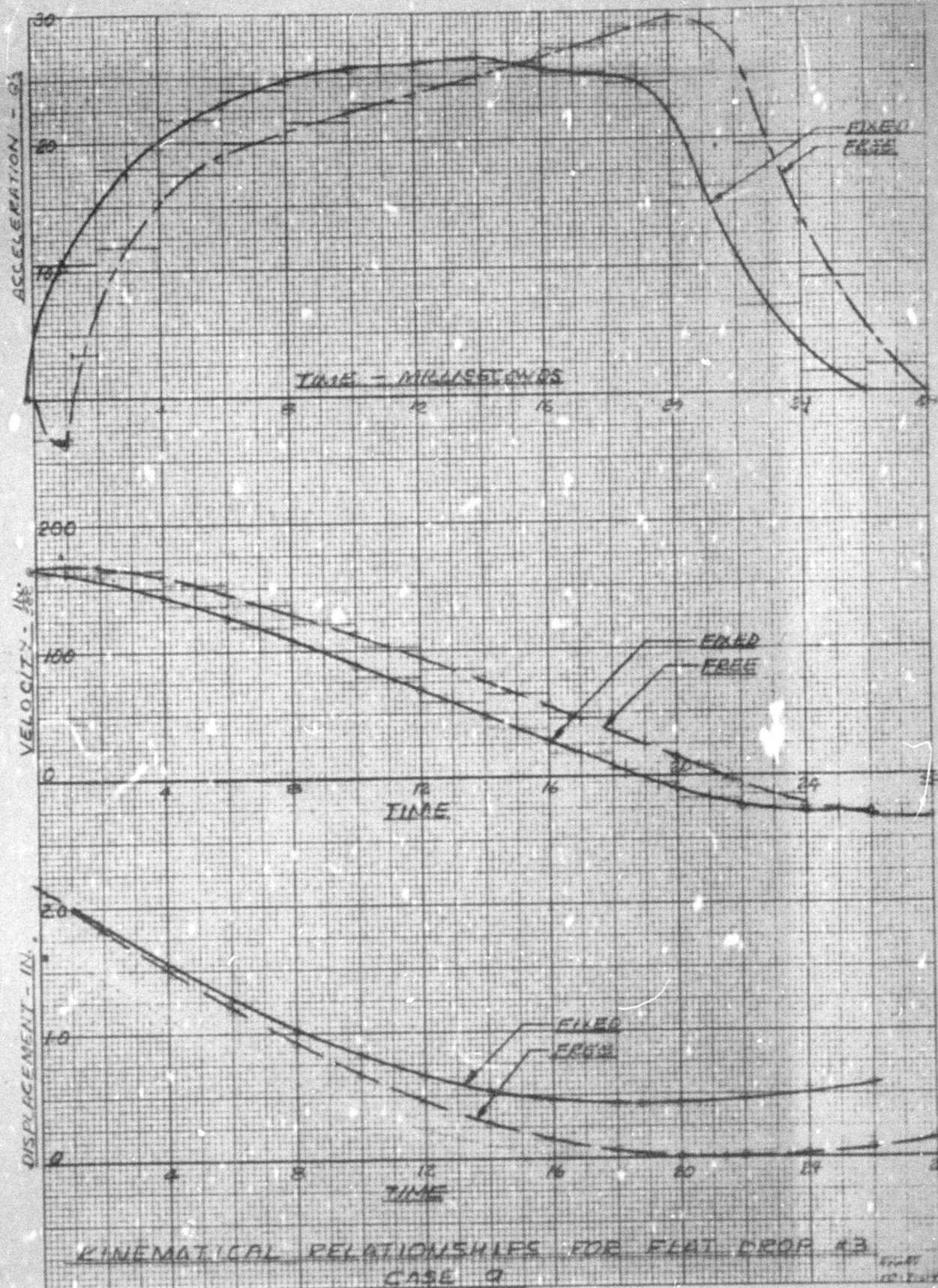Horizontal Calibration: 5 msec/cm

FIGURE 6 , ACCELERATION RESPONSE FOR CASE 9, FLAT DROP 3

Upper Trace: Fixed End of Payload
Calibration - 17.7 g's/cm and 5 msec/cm
Lower Trace: Free End of Payload
Calibration - 14.6 g's/cm and 5 msec/cm

KINEMATICAL RELATIONSHIPS FOR FLAT DROP #3
CASE 9

FIGURE 7
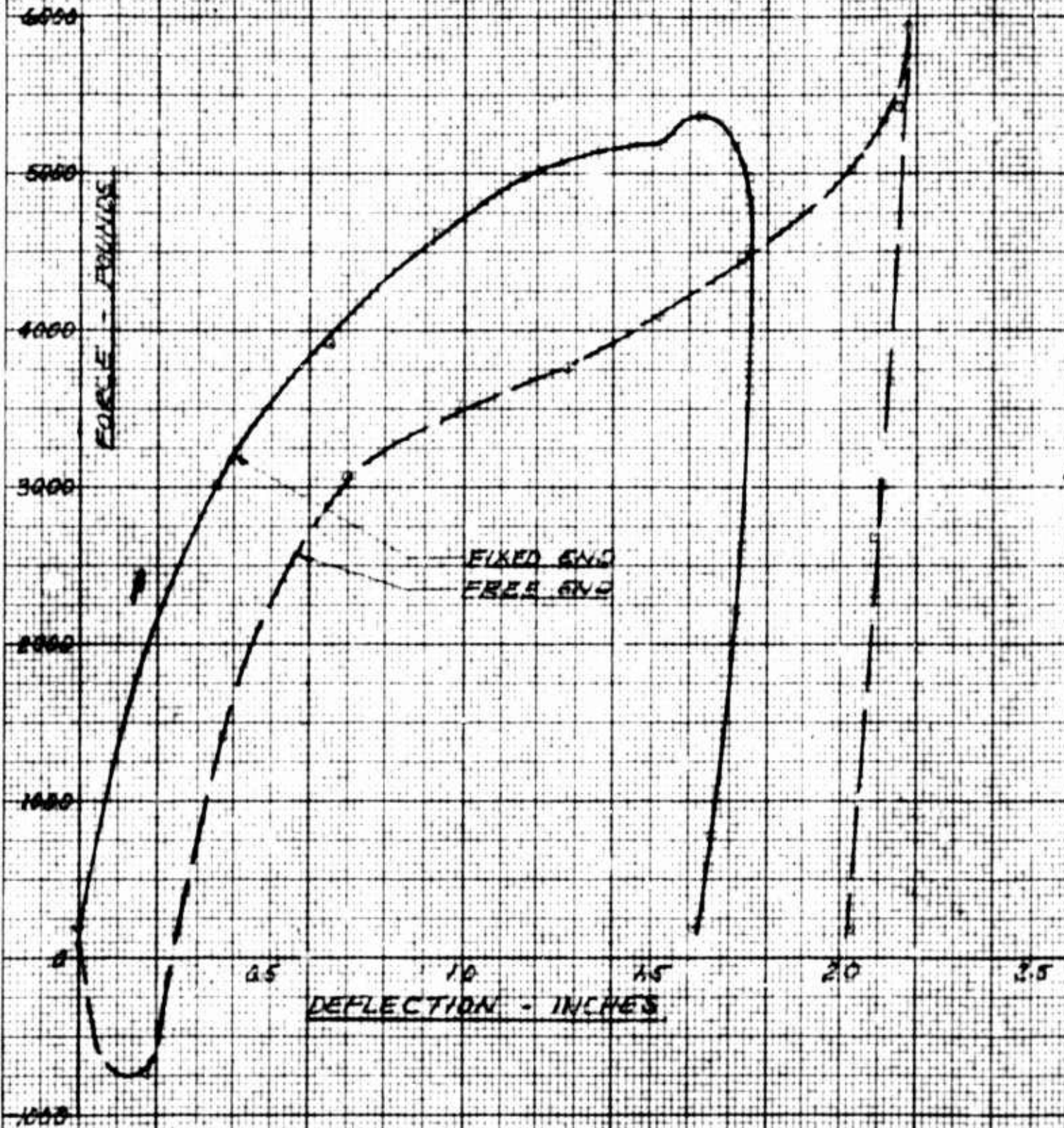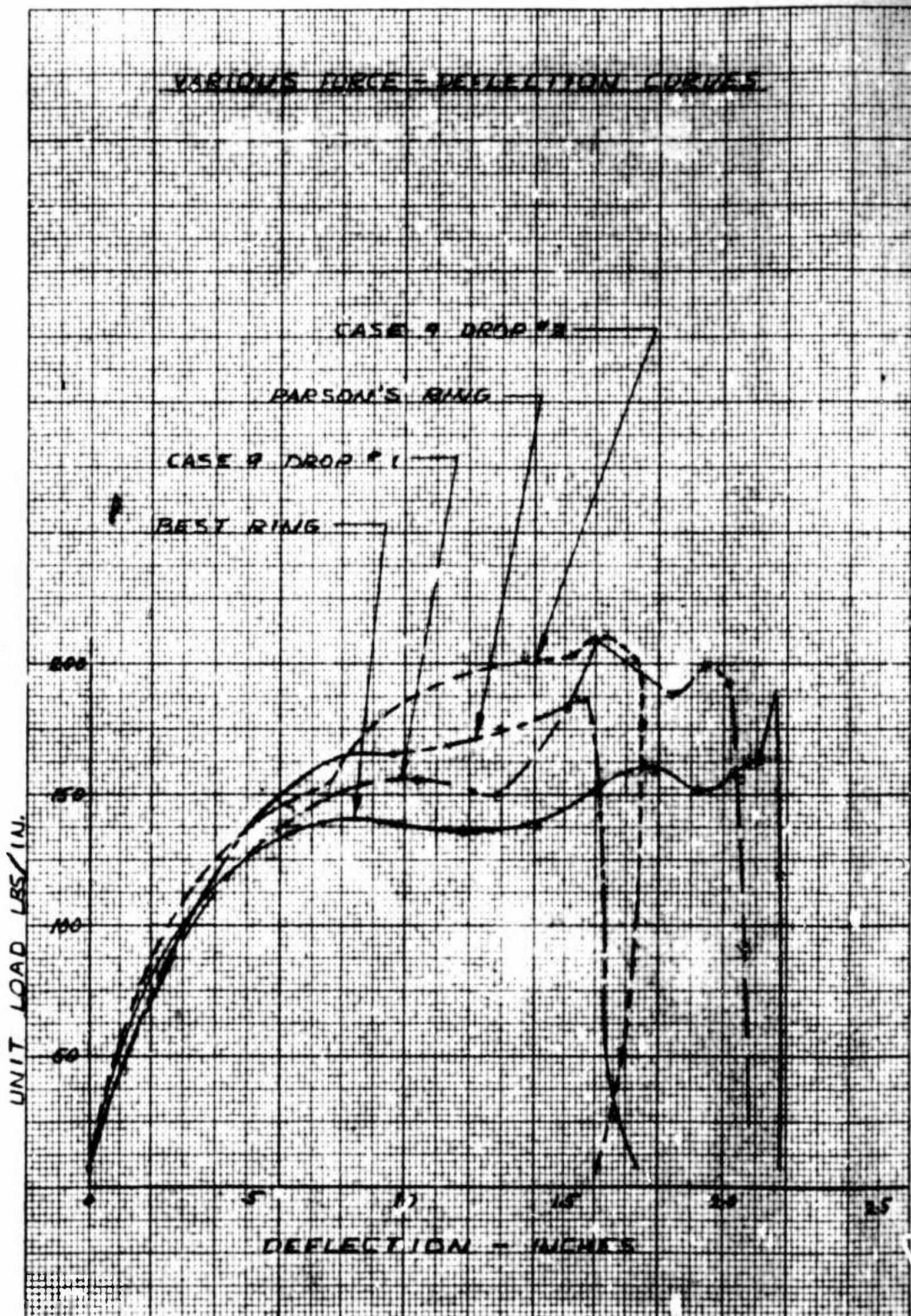
FORCE - DEFLECTION CURVES
CASE 3 - DROP 5

DEFLECTION - INCHES

FIXED END
FREE END

FIGURE 8

VARIOUS FORCE - DEFLECTION CURVES

CASE 9 DROP #2

PARSON'S RING

CASE 9 DROP #1

BEST RING

UNIT LOAD LBS/IN.

DEFLECTION - INCHES

-18-

FIGURE 9

TABLE 1

RESULTS OF FLAT DROP TESTS — CASE a

		DROP #1	#2	#3	#4	AVERAGE
FIXED END OF PAYLOAD	MAX. FAIRED CURVE	24.8	25.0	26.9	27.3	26.0
	MAX. VALUE	28.9	38.4	39.5	40.2	39.2
FREE END OF PAYLOAD	MAX. FAIRED CURVE	27.7	27.7	29.3	28.0	28.2
	MAX. VALUE	36.5	42.3	39.1	37.2	38.8
RATIO OF MAXIMUM VALUE TO MAXIMUM OF FAIRED CURVE	FIXED END	1.57	1.53	1.47	1.47	1.51
	FREE END	1.32	1.53	1.33	1.33	1.37

FOR THE FAIRED CURVE, THE AVERAGE VALUE OF PEAK ACCELERATION IS 8% HIGHER AT FREE END THAN AT THE FIXED END.

THE AVERAGE MAXIMUM VALUE IS 1% HIGHER AT THE FIXED END THAN AT THE FREE END.

TABLE 2

RESULTS OF DROP TESTS FOR CASE ~ 10

	FIXED END	FREE END
FLAT DROP #1	FAIRED VALUE 28.3 g's / 44.3 g's MAXIMUM VALUE	29.5 / 38.7
FLAT DROP #2	28.5 / 49.7	28.6 / 47.0
FLAT DROP #3	28.5 / ~ 50	30.0 / 50
FLAT DROPS AVERAGE	28.4 / 48.0	29.4 / 45.2
END DROP #1	23.8 / 34.8	
END DROP #2	24.7 / 34.8	
END DROPS AVERAGE	24.2 / 34.8	
EDGE DROP	16.5 / 17.0	

SEE FIGURE 4 FOR LOCATION OF ACCELEROMETERS.

VALUES OF ACCELERATION ARE g UNITS.

ATTACHMENT NO. 1

STATEMENT OF MAN HOURS EXPENDED

SEPTEMBER AND OCTOBER, 1964

	September Man Hours	October Man Hours
Engineering		
Senior Professional	71.0	66.0
Professional	233.0	138.0
Technician		
Drafting, fabrication, and testing	78.5	30.0
Other		
Clerical	18.5	2.0
TOTAL HOURS EXPENDED	401.0	236.0

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	DATE	1	2	3	5	7	8	9	10	11	14	15	16	17	18	21	22	23	24	25	28	29	30	1	2	3	5	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26	27	28	29	30

PROGRAM OF EVENTS

MONTHS: SEPTEMBER — OCTOBER

REFERENCE: R&D 6065, CONTRACT NO. DA-04-200-AMC-477(A)

PROGRAM OF EVENTS

Program of events Gantt chart listing activities:

- FINAL DRAWINGS
- FINAL SPECIFICATIONS
- CASE FABRICATION (HXL-12-477)
- DESIGN MODIFICATION (HXL-12-477)
- PRELIMINARY SPECIFICATION OUTLINE
- PROGRESS REPORT NO. 10
- CRITIQUE CONFERENCE
- TESTING AT PICATINNY ARSENAL (HXL-11-477)
- SHIPPING TO PICATINNY ARSENAL (HXL-11-477)
- CASE FABRICATION (HXL-11-477)
- DESIGN MODIFICATION (HXL-11-477)
- PROGRESS REPORT NO. 9
- C. Analysis
- TESTING AT BERKELEY (HXL-10-477)
- RESUME WORK ORDER RECEIVED

DATE	2	3	4	5	6	9	10	11	12	13	16	17	18	19	20	23	24	25	27	30	1	2	3	4	7	8	9	10	11	14	15	16	17	18	21	22	23	24	28	29	30	31

| MONTHS | NOVEMBER | DECEMBER |